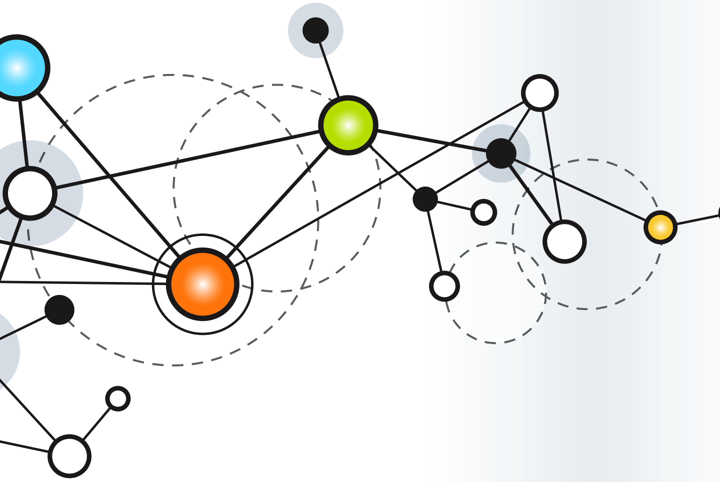
Vectoring

Accelerating the Delivery of Ultra Broadband Services



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Introduction

The need for speed continues unabated. To satisfy this need, service providers are deploying next-generation DSL equipment deeper into the network and closer to the customer. This tactic affords shorter copper wire or loops, and when combined with advanced DSL technologies, like VDSL2, allows for higher service rates. Unfortunately, these performance gains are limited by bandwidth-stealing crosstalk. The leaking signals or crosstalk between adjacent DSL services impact the rates achievable by as much as 50 percent.

If nothing is done about these noisy crosstalk signals, it is virtually impossible to deploy 100 Mbps on a single access line. A new technology called vectoring has been developed to virtually eliminate the main source of noise, Far-End Crosstalk (FEXT).

With vectoring, Ultra Broadband service of 100 Mbps can be deployed on a single copper pair as far out as 1800 ft (550 m) from the DSL Access Multiplexer (DSLAM) equipment[1]. When two pairs are bonded, 100 Mbps service can be extended to 3400 ft (1050 m)! This is a substantial improvement; however for vectoring to work effectively in the real world, a holistic approach is required which considers key network factors to maximize the ability to eliminate crosstalk. This is known as system-level vectoring.

This handbook explains what FEXT is, when it becomes a factor, and describes an innovative system-level approach to vectoring that can allow service providers to deploy this new technology rapidly and cost effectively.

1 *Using 24 AWG (0.5 mm) copper wire with Profile 17A VDSL2 technology*

Market Drivers

Nations around the world have realized that broadband has a direct impact on the well-being of their residents. It impacts the ability of companies to remain competitive, reduces the cost of healthcare while increasing its quality, and has a dramatically positive impact on education [2]. Put simply, broad-band is of national importance.

While governments, service providers and system vendors are attempting to ensure broadband is ubiquitous, they are also trying to raise broadband rates with 100 Mbps being an important target. Some in the industry refer to this premium definition of broadband access as Ultra Broadband.

2 *Dutta, Soumitra, and Irene Mia. 2008. The Global Information Technology Report 2006-2007: Connecting to the Networked Economy. Basingstoke, U.K.: Palgrave Macmillan. ITU, Measuring the Information Society,"2010.*

Ultra Broadband can enable high-quality video services; scalable, cloud-based services and new services that we cannot even conceive of yet. 100 Mbps will vastly improve our quality of experience, allowing a standard 4 MB photo to be uploaded in one-third of a second, a full CD to be downloaded in five seconds and an entire HD movie to be downloaded in less than ten minutes! Best of all, it is possible to deliver such services in a ubiquitous manner and do so rapidly and cost effectively by leveraging the existing copper infrastructure that is already connected to our homes and places of business. New solutions that leverage specialized outside plant hardened packaging (OSP DSLAMs), bonding (combining one or more pairs) and vectoring (canceling noise) make the promise of Ultra Broadband possible.

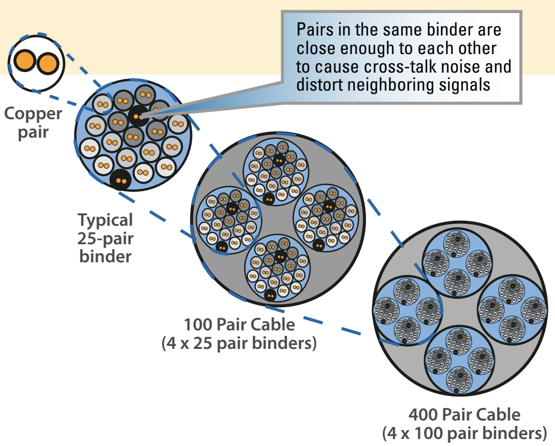


Figure 1—Individual copper pairs are grouped in binders which are sometimes bundled together to form 100-pair and even 400-pair cables.

The Problem: Deploying copper services too far away and too extensively

There are two key factors that impact the rate achievable by VDSL2: attenuation and noise.

Attenuation is a straightforward concept. The transmitted signal becomes smaller as it propagates over thousands of feet to the point of being unrecoverable past a certain distance. The longer the loop, the more attenuated the signal becomes and the lower the rate that can be delivered.

Noise can come from outside sources or other pairs in the same bundle of copper wire pairs, often called a binder. Near End Crosstalk (NEXT) is noise created by a transmitter which leaks into a nearby receiver as shown in Figure 2 below. Since VDSL uses different frequencies for downstream and upstream, NEXT is not a significant factor in VDSL systems.

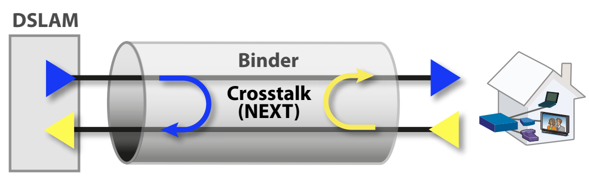


Figure 2 —Near End Crosstalk (NEXT) is not a significant factor in reducing DSL performance.

Far End Crosstalk (FEXT) is noise created by a transmitter at one end of a wire that leaks into a receiver at the other end, thereby distorting the intended signal (see Figure 3 on next page). On long loops (beyond 4000 ft or 1200 m), this noise gradually gets attenuated such that it becomes negligible once it reaches the other end of the wire. As loops are being shortened by deploying fiber facilities and DSLAM equipment closer to end customers, FEXT is now becoming a limiting factor.

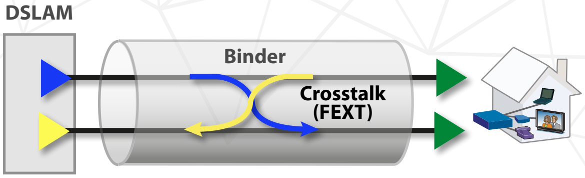


Figure 3—FEXT can actually reduce performance by nearly 50 percent.

There are two possible sources of FEXT: self-FEXT and alien FEXT. Self-FEXT, as the name implies, is noise generated (or received) within a vectoring group. Alien FEXT is noise generated by other transmitters not part of the vectoring group.

FEXT can be more than just a nuisance. It can actually reduce performance by nearly 50 percent (see Figure 4). To make matters worse, performance degrades as more users are added, with the first adjacent service causing the greatest issue. A customer that may have had high rates initially could see their rates drop to half with the addition of just a few new customers deployed in the same neighborhood thus sharing the same binder.

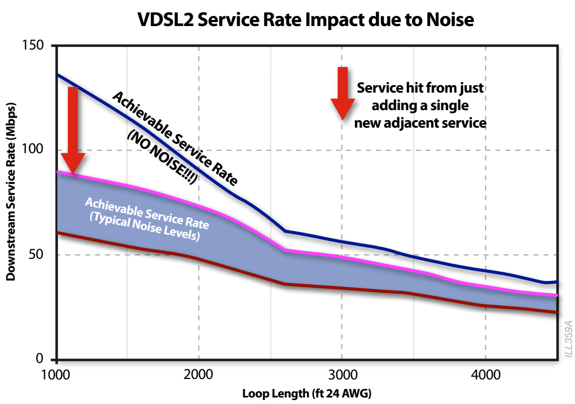


Figure 4 —It only takes one adjacent service (sharing the same binder) to substantially degrade service performance due to crosstalk noise.

Vectoring Basics

Vectoring is a technique in which the DSLAM learns the self-FEXT crosstalk characteristics of the cable so the crosstalk can be canceled. This allows the highest service level to be achieved.

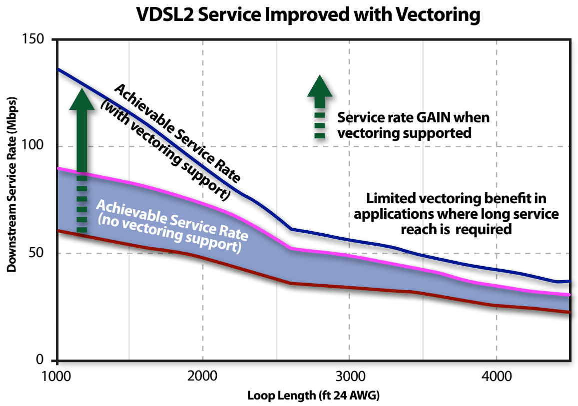


Figure 5—Vectoring was designed to eliminate self-FEXT and allow service providers to deploy advanced services of 100 Mbps and beyond.

Crosstalk noise gets attenuated over long distances. Therefore, there is little point to using vectoring on long copper loops.

Recall that FEXT is primarily a factor on short loops. This is because FEXT noise gets naturally attenuated over long distances. Vectoring is therefore a technology that only makes sense when deploying DSLAMs very close to end customers.

Vectoring—Looking at the Big Picture

For vectoring to work, the components of a broadband vectoring solution need to communicate with each other. This includes the VDSL2 modems and all of the DSLAMs.

Recall that FEXT is noise that leaks between pairs that are close to each other. The transmit signal from one end leaks into an adjacent pair and travels down this pair all the way to the receiver. If the signal is strong enough and if it is using the same frequencies as the intended signal, the two signals will combine which in effect distorts the intended signal.

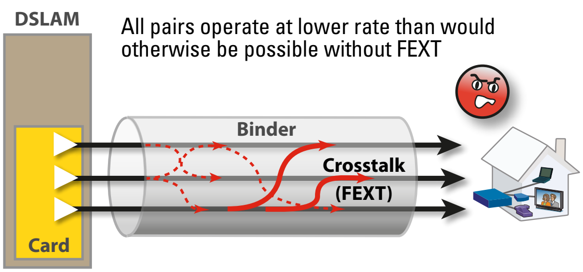


Figure 6—FEXT effects increasingly impact service performance as more services are deployed.

The first step is therefore to have all the modems take measurements and send those measurements to a central processor at the DSLAM. Most recent VDSL2 modems can perform this function with a simple software upgrade.

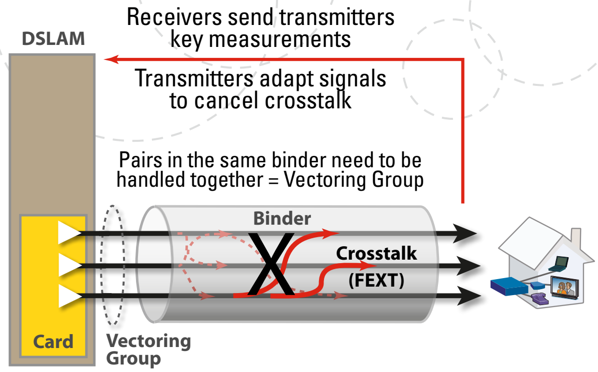


Figure 7—Services that are deployed as part of the same vectoring group allow the impact of FEXT to be eliminated.

By analyzing the measurements sent by the modems, the processor in the DSLAM can determine precisely how signals from each pair create noise on the other pairs. The vectoring DSLAM then compensates the transmit signals with corrections to cancel out the crosstalk.

This is a complex task that requires some advanced Digital Signal Processing (DSP). Very few VDSL2 chipsets support this vectoring technology in 2012, however with the advantage of Moore's law, vectoring capability is now becoming more commercially available.

In 2008, ADTRAN received the "Award for Outstanding Contributions to an ATIS Forum or Committee"*. This achievement was in recognition for its initiative in providing the industry with a FEXT Channel Model needed for the analysis of FEXT cancelation techniques used in vectoring. ADTRAN, with five million VDSL ports deployed, currently holds a top 3 DSL market share position globally according to Infonetics.

ATIS—Alliance for Telecommunications Industry Solutions

The Vectoring Group

As described earlier, vectoring works across groups of pairs in the same binder (i.e. they are close to each other physically). This is called a Vectoring Group. Some chipsets only have enough processing capacity to deal with 24 or 48 pairs in a vectoring group. Furthermore, all pairs in a vectoring group have to be connected to the same chipset for vectoring to work with some chipsets.

If even just one VDSL2 pair in a binder does not participate in the vectoring group, the performance of all pairs in the binder is severely affected. It can even affect pairs in other binders within the cable. In fact, the impact is so great that vectoring no longer has significant benefit as a single alien or non-vectored service can affect a hundred or more vectored services.

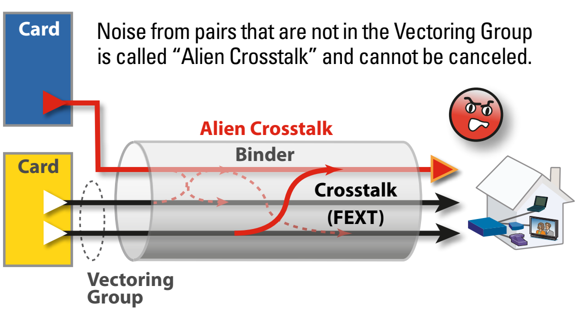


Figure 8— All pairs need to be in the Vectoring Group otherwise vectoring does not provide any benefit.

This huge disruption in the overall well-concerted effort occurs because an alien pair has no idea what is going on in the binder and cannot communicate with the processor that is managing the signals in the binder, therefore it cannot be considered as it counters for the overall noise.

The System Level Approach to Vectoring

The solution to the problem of alien pairs is to take a system-level approach to vectoring known as system-level vectoring. This implies new capabilities that oversee hundreds of pairs and can coordinate the various transmitters, even if they are on separate cards or DSLAMs.

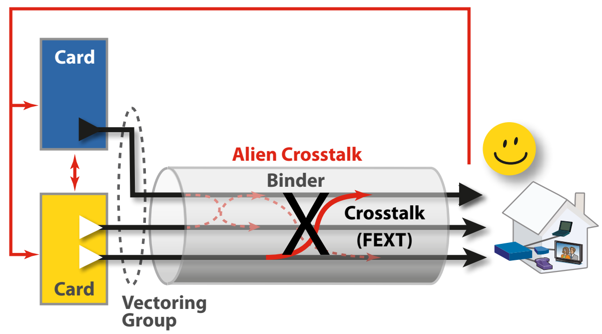


Figure 9— Multiple OSP DSLAMs or Line Cards need to work together as a "system" so that vectoring can be performed across line cards in a DSLAM or across DSLAMs

Managing crosstalk across line cards and systems is a complex task but it is necessary to ensure all pairs in the cable are managed together. Failure to take a system-level approach leads to a solution that is very limited, and worse, it leads to a solution that works for a while and then breaks down catastrophically flooding service provider call centers.

Vectoring and Binders

As mentioned previously, cables are groups of multiple binders, while binders are bundles of copper pairs. Binders emanate from one central location to a group of customers. It is common for a telecom installation to have several binders going in different directions depending on which cable they reside within.

A service provider will typically install one DSLAM to serve customers in the area and wire new customers to the DSLAM as they sign on (see Figure 10 below). When the ports on the first DSLAM are exhausted, a second DSLAM is added to support new service capacity. New customers are then wired to the new DSLAM as they sign on to the service.

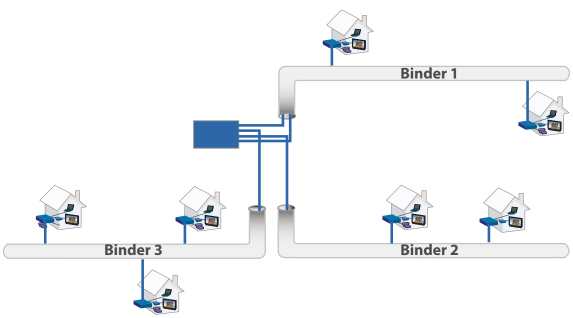


Figure 10—There is not a one to one relationship between binders and DSLAMs

The result of multiple DSLAM deployments is that pairs in the same binder are connected to different DSLAMs (as shown in Figure 11). If the DSLAMs do not support system-level vectoring across the DSLAMs, the new pairs will cause substantial noise that will not be canceled. As a result, the rates for customers in the binder with the new pair could drop by 30 to 50 percent!

Figure 11

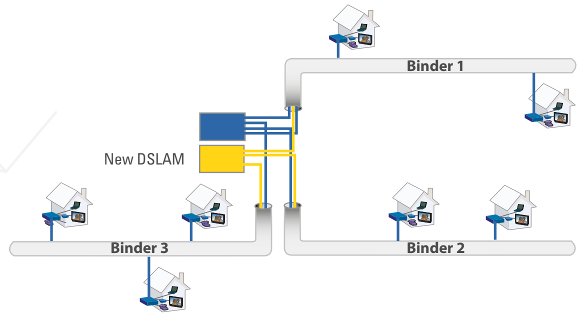


Figure 11—When a new DSLAM is deployed to add service capacity system-level vectoring becomes a key requirement.

Binder Management and Vectoring Versus System-level Vectoring

One way to ensure that separate DSLAMs do not transmit onto pairs in the same binder is to rewire customers so that each binder is handled by a single DSLAM. This approach, referred to as binder management, is generally problematic and expensive over the long term. It requires substantial ongoing work to continuously rewire customers and leads to stranded ports. Additionally, inter-binder crosstalk has been shown to reduce the overall cancelation benefit significantly.

Imagine that the first DSLAM is driving a number of pairs in the first binder (light blue) and it has two spare ports. Three customers served by a separate binder (light grey) now want broadband. The existing DSLAM (yellow) does not have enough ports so a second DSLAM (or a new card) is deployed. You cannot use the remaining two ports on the first DSLAM (light blue) since, in this case, vectoring groups cannot span across cards in a system or across DSLAMs (see page 14, Figure 12).

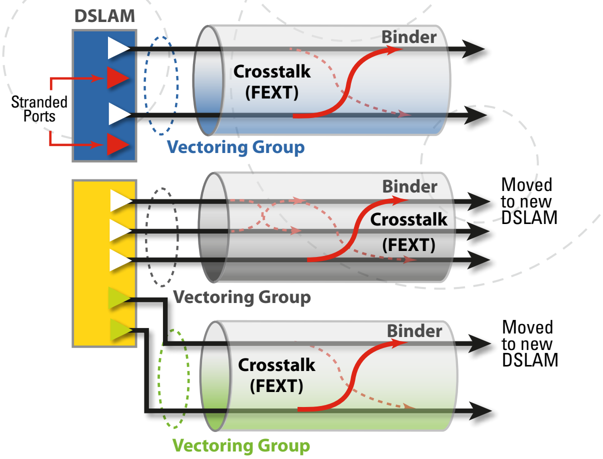


Figure 12—Substantial effort is repeatedly incurred as customers are removed or added.

All three new customers need to be served from the new DSLAM (dark blue) effectively stranding two ports on the first DSLAM (light blue).

As customers are removed and added, technicians have to continue rewiring the binders, which is costly and the number of stranded ports grows.

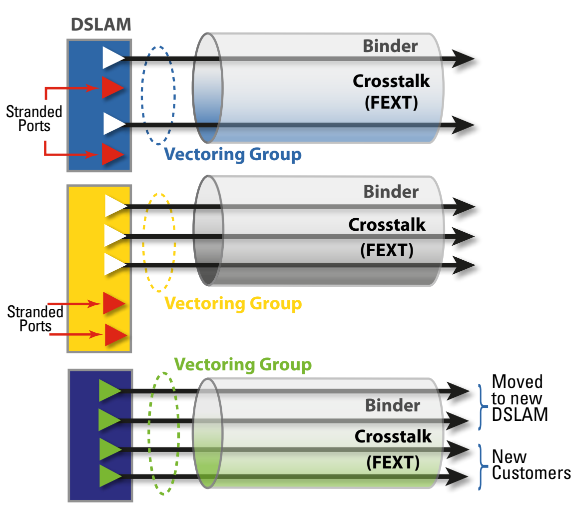


Figure 13—After customer rewire the new service installation continues to support vectoring. There is a better way.

If the DSLAMs had the ability to coordinate with each other the first two ports could come from the first DSLAM and the third port could come from the new DSLAM. In effect, the two DSLAMs behave as one system when it comes to vectoring in terms of system-level vectoring.

System-level (Cross-DSLAM) Vectoring

The only way to truly deploy vectoring in a scalable and cost-effective manner is to take a system-level approach. Such an approach implies the need for high-performance processing engines and very-high-speed communication buses between the vectoring processing engines and the VDSL2 chipsets. This approach should work across cards in a system and even between DSLAMs at the same location.

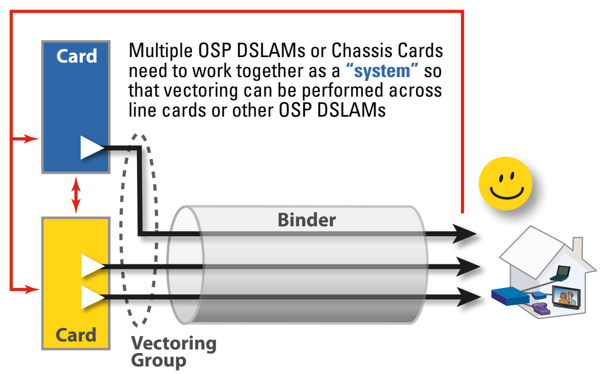


Figure 14—System-level vectoring is the only way to effectively capitalize on the benefits of vectoring.

A system-level approach that works across cards in a system or across DSLAMs ensures that rewiring is never required. It also ensures that ports are never stranded. As DSLAMs or cards are added, ports are added to vectoring groups and no subscriber ever sees a sudden drop in performance – leading to a much better customer experience.

For a system-level vectoring approach to work, DSLAMs and the VDSL2 chipsets they used must be designed with a system-level approach. The chipsets need to be able to communicate with each other and more signal processing is required to deal with vectoring across a large number of ports.

First-generation chipset solutions have taken different approaches toward their ultimate plan to system-level vectoring. Early adopters had to choose to move to either board-level vectoring or system-level vectoring.

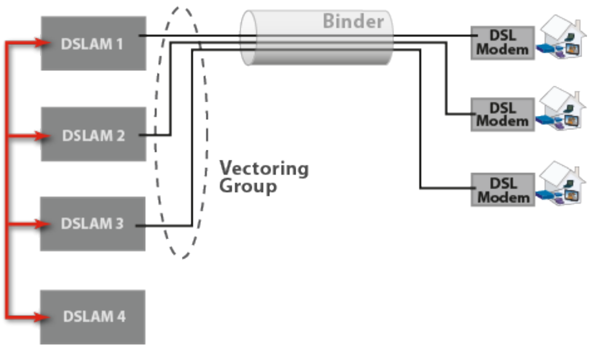


Figure 15— System-level vectoring can be implemented not only across cards in a DSLAM but across several DSLAMs.

Some vendors chose to implement their designs as exclusively one or the other. ADTRAN has taken a best of both worlds approach to its designs allowing for board-level convenience for low-cost initial deployment with full system-level upgradability as customer take rates rise.

The Payoff

Service providers are constantly seeking ways to deliver higher revenue services to more subscribers and remain competitive while doing so. Vectoring is an important piece of the puzzle that allows them to do that. Vectoring can be used to deliver 100 Mbps on short loops or 50 Mbps on longer loops. Combined with other technologies such as pair bonding, vectoring can help deliver hundreds of Mbps over thousands of feet. Without vectoring, it is nearly impossible to deliver 100 Mbps service using a single pair. With vectoring, 100 Mbps can reach approximately 1800 ft (550 m) and when two-pair bonding is used, 100 Mbps can be delivered to 3400 ft (1050 m) Combining bonding and vectoring can effectively deliver hundreds of Mbps to premium customers.

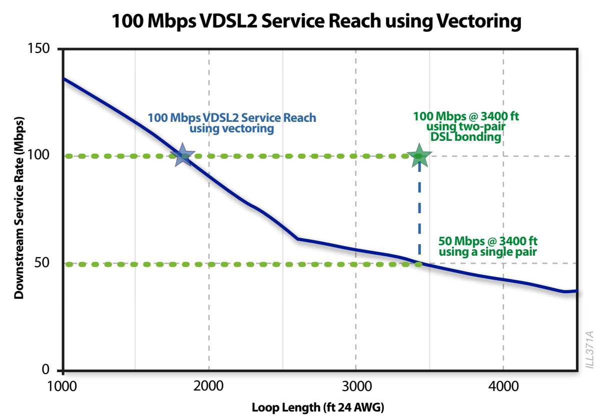


Figure 16 — With the implementation of VDSL2 vectoring 100 Mbps services can be extended over 1 km beyond a service provider's point of presence.

Vectoring can also help extend the reach of 50 Mbps service. For example, without vectoring, 50 Mbps can be delivered over loops up to 1500 ft (450 m)[3]. With vectoring, the reach is stretched to approximately 3400 ft (1050 m). That implies a

3 *Using 24 AWG (0.5 mm) copper wire with Profile 17A VDSL2 technology*

substantially larger number of people that can sign up for 50 Mbps service.

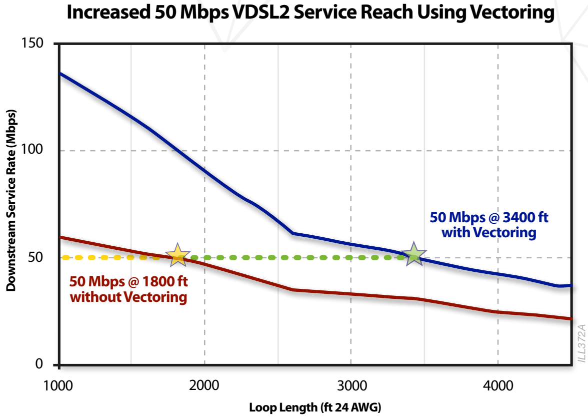


Figure 17 — VDSL2 vectoring allows 50 Mbps services to be extended two times farther than previous DSL implementation.

About ADTRAN

ADTRAN, Inc. is a leading global provider of networking and communications equipment. ADTRAN's products enable voice, data, video and Internet communications across a variety of network infrastructures. ADTRAN solutions are currently in use by service providers, private enterprises, government organizations, and millions of individual users worldwide. For more information, please visit ***www.adtran.com***

Accelerating the Delivery of Ultra Broadband Services.

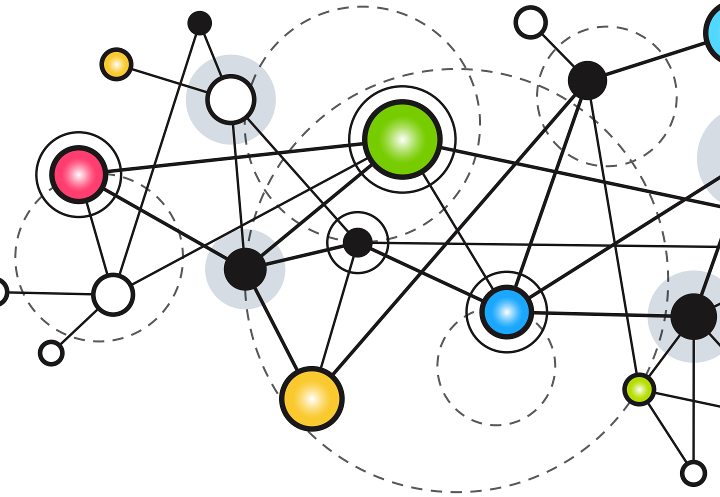
Vectoring is a complex but effective new capability being integrated into next- generation DSLAMs. ADTRAN's next-generation DSLAMs include, vectoring that supports a system approach right from the start. This allows service providers to rapidly deploy premium services without the cost and delays incurred when having to constantly rewire binders and the associated stranded ports.

Conclusion

Service providers are seeking new, cost effective and quick-to-deploy solutions to deliver premium services in the range of 50 to 100 Mbps and beyond. They are being supported by governments around the world because it has been proven that broadband enhances a country's competitiveness, improves education and saves money delivering health care.

By deploying new Ultra Broadband solutions, service providers can reach their broadband goals with game changing economics. Ultra Broadband solutions are generally characterized by:

- small, specialized, sealed packaging that can be installed anywhere—no pad construction
- new powering solutions including line power and reverse power—no power construction
- equipment that is deployed closer to customers using existing access facilities—no fiber construction
- bonding: the ability to combine pairs to increase service rate and reach
- vectoring: the ability to minimize the impact of FEXT noise to increase service rate and reach



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